THE ELASTIC LIGATURE AND THE LIGATURE METHOD.[1]

HISTORICAL AND EXPERIMENTAL DATA FROM THE SURGICAL LABORATORY OF THE MEDICAL DEPARTMENT OF THE UNIVERSITY OF CALIFORNIA.

BY DUDLEY TAIT,
OF SAN FRANCISCO, CAL.

THE paucity of accurate data concerning the history of the elastic ligature has prompted the present communication, in which the topic is also viewed from the standpoint of experimentation. No claim to originality is made, in view of the conceded threadbare condition of the subject to which the experiments relate: gastric and intestinal suture. To an Italian surgeon, Grandesso Silvestri, of Vicence, we owe the first published reference to and experimental study of the elastic ligature (1862). A year later, Richard, acting upon Prof. Trousseau's advice, used the elastic ligature in various cases, 17 in all (vascular growths, tumors of the breast, fistulæ in ano, etc.), and reported the results in a brief memoir (1863). Subsequently (1865) two English surgeons, Bryant and Henry Lee, resorted to this method for the removal of lipomata, hemorrhoids and pediculated growths, and in 1871 Henry Lee reported to the London Clinical Society an ablation of the tongue by means of the elastic ligature.

The same year Grandesso Silvestri published a second memoir on the subject, confirming and completing his original conclusions.

The above mentioned trials passed almost unnoticed. Hence Dittel's announcement of the discovery of the elastic ligature before the Medical Society of Vienna, 1873. His attention had been drawn to the possibilities of this method of treatment by the following very curious incident:

[1] Read before the San Francisco County Medical Society, Oct. 11, 1904.

On the 5th of March, 1872, a girl, aged 11 years, was admitted to the hospital for marked headache. Examination showed a suppurating wound encircling the entire head and containing an elastic cord which was forthwith removed. According to the patient's statement, she had often been severely punished by her mother-in-law for the untidy condition of her hair, and had sought long ago to avoid further chastisement by continuously wearing a net with an elastic cord stretched tightly around the head, thus preventing the displacement of the net. Symptoms of meningitis appeared at an early date, death occurring March 21st. The necropsy showed section of the soft parts and of the bones of the skull, as if made by a fine saw. With the exception of a few trabeculæ, the section of the cranium was complete.

Encouraged by this demonstration, Dittel immediately applied the elastic ligature in over 200 cases: Erectile tumors, anal fistulæ, ablation of cancer of the breast, ligation of vessels, prolapsus ani, phymosis, castration and amputation of the lower limb. Thus Dittel's contribution to the elastic ligature brought the method into prominence. Nevertheless, the priority belongs to Grandesso Silvestri. Even Dittel himself (Oct. 7, 1873), with very commendable loyalty, publicly acknowledged the justice of Silvestri's claims. Contemporary German writers, for reasons unknown, fail to mention the latter incident.

Grandesso Silvestri used the elastic ligature in lateral intestinal anastomosis, but, finding it unsatisfactory, discarded it immediately. Gaston of Atlanta (1884), was the first to employ the ligature method for the establishment of a channel of communication between hollow viscera. His cholecystduodenostomies by this method were not satisfactory, however, and Gaston voiced his preference for the suture method.

Shortly afterwards (1888) Bardenheuer reported a series of intestinal anastomoses with a round rubber cord, 1 to 1.5 mm. in diameter, forming a chain ligature. In 1891 McGraw published his first address on the elastic ligature, simplifying Bardenheuer's technique but retaining the latter's round rubber ligature material.

Although ably and adroitly presented, the cause of the elastic ligature failed to make converts, and was soon abandoned by its chief advocate.

Then followed a series of researches by Russian sur-

geons. Podres (1898) used two silk ligatures in the shape of a cross, thus obtaining a star shaped opening within four days. Podres applied this method in two patients. The result in one case was excellent; the second patient died on the sixteenth day. Sokoloff, using the same method, reported three gastro-enterostomies with two failures to cut out.

After several similar failures Podres modified his method by circumscribing a rectangular area 4x6 cm. by means of four silk ligatures traversing all the gastric and intestinal layers. Schalita, Sokoloff, Varnex and Tedoroff (1899) reported numerous gastric anastomoses by this method, but the results failed to convince other Russian or the Continental surgeons. Porta (1899) modified McGraw's technique by using a rubber band and Raffa further complicated the question with two elastic ligatures. Modlinski (1899) substituted rubber for silk in Podres' method. In 1892 Postnikow proposed an oval excision of the seromuscular layers of the stomach and intestine, followed by ligation of the protruding mucosa.* Trojanoff (1893) and Lauenstein (1894) each reported a success in men with this method. Mugnai, a year earlier, had used the thermocautery instead of the knife, prior to ligating the mucosa.

In 1901 McGraw reiterated his statements regarding the elastic ligature, and reported a series of successful trials with with what he calls "a method of my own invention" (N. Y. Med. Jour. 1901, p. 133). While McGraw is in no sense the originator of the elastic ligature, he nevertheless deserves unstinted praise for having rejuvenated, made practical and ably advocated this very interesting question of operative technique.

ELASTIC LIGATURE.

Size of the Elastic Ligature.—While the round rubber ligature used by Bardenheuer measured only 1.5 mm. in diameter, that employed by McGraw measured 3 to 5 mm. Our experiments on large dogs, and seven cases in man, proved conclusively the superiority of a much smaller size. The flat rubber bands 1 to 2 mm. in width, as are commonly found in

* This procedure was recently recreated by R. C. Coffey, of Portland, Ore. (Medical News, Nov. 4, 1905.)

stationary stores, gave excellent results in intestinal anastomoses.

Quality of Rubber.—Pure rubber, capable of being stretched at least five times its length, should be selected.

The usual rectangular mode of placing the elastic ligature is the quickest and safest. All other methods make irregular and small cut-outs.

The plan of punching out a stoma originated with Bardenheuer (rubber-chain ligature). Podres sought to obtain the same effect by using silk ligature in triangles and squares.

Subsequently the problem received some attention from C. M. Cooper, of San Francisco, and later from Weir and Maury, of New York, who recently disinterred the old method of Podres, rendering it still more complicated. In view of studying the merits of the punching-out plan, a large number of intestinal anastomoses were made with rubber, silk and twine, enclosing areas of diverse shapes—squares, rectangles, Greek stars, single and double triangles. The results showed a high mortality whenever the simple rectangular method was departed from and the rubber openings were invariably the most satisfactory. All anastomotic openings eventually become oval or circular.

The mode of securing the knot suggested to McGraw by Hickey is, at best, a clumsy device. The more recent mode of tying the rubber with silk or thread is merely a modification of the procedure employed years ago by Sir Henry Thompson (1874). A simpler and equally safe method is to place a clamp on the rubber strands previously drawn taught; a silk ligature can then be placed beneath the clamp, the rubber cut short and the clamp removed without fear of the knot slipping.

In a series of over 150 operations, comprising 12 different interventions on the stomach, intestine, gall-bladder and urinary bladder, rubber cord, 3 mm. in diameter and flat rubber bands 1 to 2 mm. in width and 1 mm. in thickness were used, with the ordinary or the Reverdin needle.

The time necessary for the elastic ligature to cut through, varied considerably. However, with a fixed degree of constriction the time required for the cut-out is directly propor-

tionate to the amount of tissue in the bight of the knot. This fact is well illustrated in Bardenheuer's method of gastro-enterostomy by elastic chain ligatures in which the cut-out takes place within two days.

The shortest time noted in any of the dogs was three days for the intestine and four days for the stomach. In the majority of dogs the cut-out took place in four days (stomach) and three days (intestine); in the early experiments, more time was required with cats (four to six days), but later the constriction was more properly made and the results resembled those obtained in dogs. Variations in the time of the cut-out may be partly due to the quality of rubber. Old or boiled rubber may lose much of its elasticity. The degree of constriction is undoubtedly the principal and most important factor.

In estimating results, the intestine will be considered independently of the stomach.

Intestine.—The following sufficiently accurate mode of comparison was adopted:

1st, A series (5, 6, 7,) of lateral anastomoses were made at the same séance by the rectangular-ligature method with various materials,—rubber, silk, twine, plain and chromic gut, of various sizes.

2d, Several lateral anastomoses by the various suture methods,—the two-row suture, the continuous or interrupted Connell suture.

Necropsy specimens of a large series of these experiments show:

1st, A considerable number of failures to cut-out when No. 1 catgut and No. 1 silk are used.

2d, A few failures with linen thread of silk No. 2 and 3.

3d, No failure with properly placed rubber.

4th, In one instance the rubber (1x1 mm.) was found encysted, having evidently broken.

5th, The size and shape of the anastomotic opening were somewhat influenced by the nature of the ligature material. The opening produced by rubber exceeds all others in the transverse and longitudinal diameters.

6th, In *successful* intestinal anatomoses, the cut-out re-

quired more time with rubber than with any of the other materials, all of which could be handled more expeditiously and with a greater degree of immediate sero-serous approximation than rubber. The only somewhat bulky knot was that of rubber.

7th, The puckering of the gut produced by the ligature sometimes persists more than thirty days. This is particularly noticeable in intestinal anastomoses measuring more than 5 cm. In these cases the opening is seldom clean cut; on either side and in the middle third of the opening an elevated granulating fold will be frequently found as late as the fourteenth day.

This is more or less present at an early date in all methods of intestinal anastomosis. The elimination of the protruding parts between the two flaps of mucosa takes place by necrosis or by the destroying power of those crypts which have returned to their embryonic type (Mall).

8th, The stoma made with rubber can always be recognized; it is large, clean cut, and has a sharp, regular edge. The Connell stitch produces a much shorter and narrower stoma, owing to the constant presence of a bridge formed by the protruding intestinal layers. Regeneration of the mucosa is somewhat slower than with the elastic ligature.

9th, The classic two-row suture method makes a stoma comparing favorably in width and length with that made by rubber. It is, however, generally less regular in outline. Furthermore, regeneration of the mucosa requires more time, and omental adhesions are more pronounced than in both of the above methods of anastomosis.

No apparent contraction was noted in elastic ligature openings after a period of twelve and sixteen months.*

* The observations of the Mayo Brothers regarding the closure of the anastomotic opening in cases of patulous pylorus were not substantiated in any of the dogs operated on and kept under observation for several months. Furthermore, the findings of the French, German and Swiss schools (Terrier, Hartmann, Montprofit, Kocher, Witzel and Roux) do not corroborate the Mayos' assertion. The occurrence of this complication in the Mayos' early cases suggests the presence of slight local peritonitis due to over-manipulation or possibly faulty suturing, causing an inordinate amount of granulation tissue.

The *modus operandi* of a successful anastomosis by the ligature method is conclusively illustrated by the inspection of the parts immediately after the operation. It will be noticed, first, on the peritoneal surface of the bowel, that the ligature material (silk or twine) has cut through the serous and mucous layer and the major portion of the muscular layers, leaving merely a few circular muscular fibres and some submucosa; second, on the mucous surface of the bowel, when the ligature fails to cut through the muscular layer, the submucosa retains its vascular supply, and consequently does not undergo necrosis. It would seem, therefore, that the bridges of tissue in the anastomotic opening, noted by all experimenters, are in part due to insufficient or irregular constriction of the parts involved. In other cases of totally inadequate constriction, the mucous surfaces show, after eight days, a lineal scar of variable depth, when catgut is used, or two minute orifices, surrounded by scar tissue, in which the silk or twine (rectangular) ligature hangs loosely.

In view of the immediate destruction of the various intestinal layers by the use of the ligature method (silk or twine), several attempts were made to obtain an anastomotic opening by removing the ligature and then circumscribing the entire previously ligated area with Lembert sutures. Failure followed in all cases. A certain amount of necrosis occurs, but a lineal cicatrix will be found as early as the sixth day. Microscopic sections of specimens of one hour, one and two days, proved conclusively the impossibility of securing anastomosis by this method. Mention is made of these negative results in view of the recent erroneous statements of Werelius (J. A. M. A., 1904).

Stomach.—Rubber cord, 2 or 3 mm. in diameter, placed in the usual rectangular manner, never failed to cut-out. In all cases inspected during the first and second days the pyloric end of the stomach seemed to be in a state of contraction. This condition was not present on the third day. Dilatation of the stomach was present in a few cases during the first and second days.

For comparative purposes, ten dogs and six cats were sub-

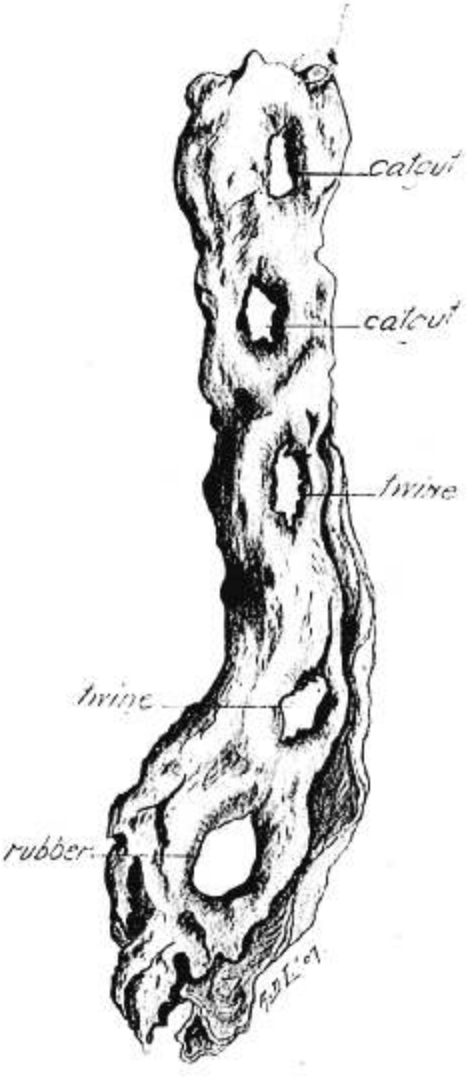

FIG. 1.—Natural Size.

FIG. 2.—Natural Size.

FIG. 3.—Rubber—15 days.

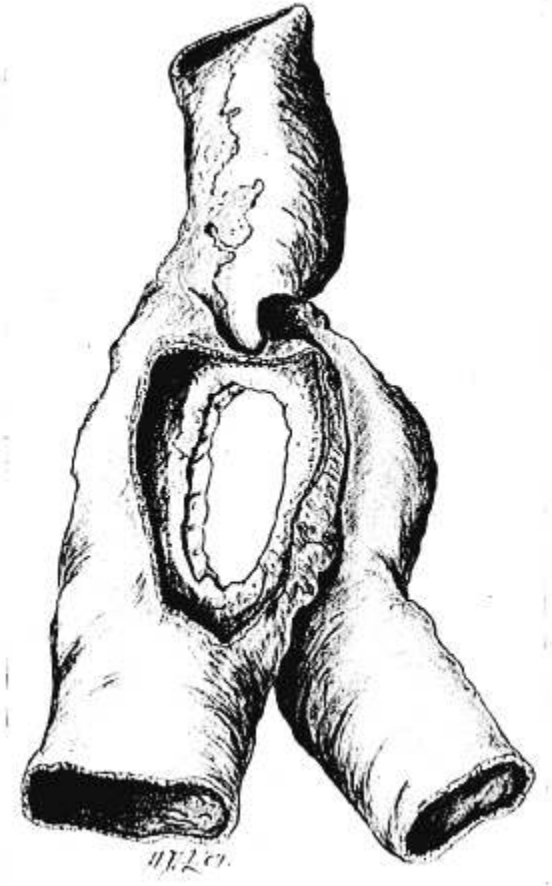

FIG. 4.—Two-row Suture (10 days.)

jected to a gastroduodenostomy* (Villard, Kocher) and simultaneously to a posterior gastro-enterostomy. Rubber, in rectangle, was used for one operation; and twine, in triangles, for the other. The results were uniform. Aside from being far less expeditious, twine in triangles proved less safe, more bloody, necessitated more extensive sero-serous suturing, caused more pronounced and more lasting kinking of the gut and more irregularly shaped and no larger openings than the elastic ligature used in the usual rectangular manner. Failure to cut-out was occasionally noted with twine.

We feel, therefore, justified in condemning all attempts to render difficult and dangerous a very simple and safe procedure.

In view of studying the degree of shock resulting from the use of the ligature method, the following operations were performed at one séance on a pregnant slut: 1 gastro-enterostomy, and 2 entero-enterostomies. Evidence of pain during the first 36 hours was the only noticeable feature;—the animal ran about as usual on and after the third day, and gave birth to five pups of normal size on the seventh day.

The following was done on a male dog: 1 cholecysto-gastro-enterostomy, and 4 lateral anastomoses.

In a third case eight lateral anastomoses were made. These dogs remained without food for two days, then gradually resumed their normal state and were subsequently re-operated, in one case as many as six times. Anastomosis made under local anesthesia caused very marked pain when twine or silk was tied in triangles or squares. With rubber, in rectangle, pain was much less apparent.†

Speed.—The ligature (intestinal) can be placed, tied and cut within fifteen seconds, and an additional anterior supporting mattress suture requires about the same length of time.

A series of over fifty ligature operations (catgut, silk) show that protecting sutures are not indispensable in intestinal anastomosis. Under these circumstances omental adhesions were seldom noticed, and in cases of reoperation after thirty

* Finney's operation can be done with the elastic ligature, but failures are not infrequent.

† Halsted and Mall noticed that sero-serous union frequently took place before the operation was completed.

days none was found. The posterior row of protecting sutures is entirely superfluous in view of the perfect sero-serous approximation, and the sole purpose of the anterior suture is to cover an immoderately large knot. Microscopic sections show clearly the advantages of protective sutures when rubber is used, although they may be dispensed with, as proved by a long list of successful gastric anastomoses in the dog. However, when considerable tissue is included in the bight of the ligature supporting sutures are in order. Under such circumstances a posterior row and a single anterior mattress suture will prove expeditious and thoroughly adequate.

These facts are rather significant when we recall Gregory Connell's loud utterances relative to the "knot within the bowel," a feature which made but little impression on experienced American surgeons and none at all on foreign surgeons. As early as 1889 Chaput proved the absence of ill results from through and through intestinal sutures with the knot outside of the bowel, and subsequently Sonnenberg advocated and successfully practiced a similar method in appendicectomy.*

Convinced of the reliability of the results of experimental findings in the question of supporting sutures, we made (Aug., 1904) a lateral anastomosis in the pelvic colon in order to circumvent the consequences of a kink following the resection of a sarcoma of the bowel. Braided silk was used in the usual rectangular mode, and a single narrow mattress catgut suture sufficed to cover the knot. Immediate and final results were perfect; no peritoneal reaction was noted. The patient passed gas the first day and had a large formed evacuation of the bowels the sixth day. Having eleven months previously made a lateral anastomosis in this patient by the two-row suture method, we were able to appreciate the simplicity of the ligature method.

The claim that union by first intention occurs with the elastic ligature in gastro-intestinal anastomosis is most easily disproved by the very elementary consideration of pressure

* It is not commonly known that the essential part of the so-called Connell suture—the through and through continuous stitch—is due to M. E. Connell (1888). Gregory Connell modified his father's suture by placing the knot within the lumen of the gut.

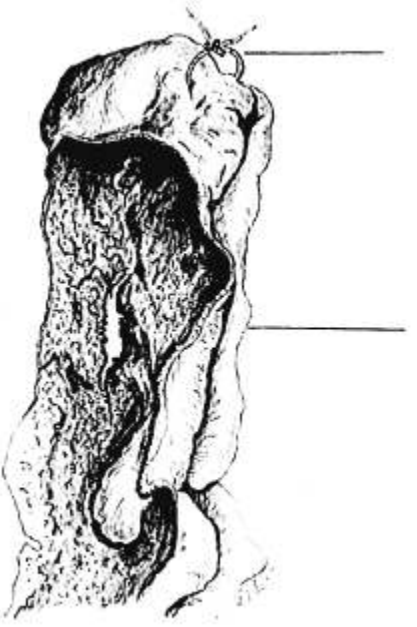

FIG. 5.—Twine (rectangular).

FIG. 6.—Gastro-duodenostomy and Gastro-enterostomy.

necrosis in a septic medium like the intestinal canal. Furthermore, microscopic sections of ligature specimens of two to three weeks, frequently show a marked gap of granulation tissue between the gastric and intestinal epithelial borders.

Again, it is stated that there is no escape of feces and therefore no exposure to peritoneal infection from the bowel contents. Inspection of the portion of the ligature which has traversed the bowel will invariably show the presence of feces in the unprepared cases, and culture tubes inoculated with the rubber in question always give a luxuriant growth of bacteria in the prepared cases. It may, therefore, be safely asserted a priori that asepsis neither exists during nor after an operation with the elastic ligature.

Circular Ligature.—The results of circular ligature in the intestine were first noted in the clinical studies of several French surgeons, Quénu, in particular, and their findings were confirmed experimentally by Genersich, in Germany, and by my clever friend, J. Henry Barbat, of San Francisco.

The results vary according to the condition of the bowel; in cats previously purged or starved for twenty-four hours, a tight ligature causes a necrotic process similar to that described in lateral anastomosis by the ligature method. The serosa completely covers the ligature within 36 hours, and on or about the fifth day the ligature passes into the intestine, the lumen of which becomes pervious as early as the 9th day. When the ligature was left loose, it remained *in situ*, and always failed to pass into the gut, death occurring from inanition sometimes as late as the nineteenth day. No signs of ileus or peritonitis were noticed in either of the two foregoing groups of experiments. In unprepared animals early death from toxemia frequently resulted. No peritonitis was present at necropsy.

The preceding statements were verified by three varieties of experiments:

1st, A ligature (silk or rubber) was placed on the afferent loop in von Hacker's gastro-enterostomy with entero-enterostomy.

2d, Lateral anastomosis between the ileum and pelvic colon with ligature on distal end of ileum (Barbat).

3d, Circular ligature on the small intestine (Genersich),

or colon. Specimens from all three varieties of cases show the lumen of the gut almost normal in diameter with a lineal scar plainly apparent beneath the serous coat.

In the domain of vascular anastomosis the ligature method proved very serviceable (Eck's fistula and Carrel's anastomosis between the carotid artery and jugular vein).

While our clinical experience* does not permit us to speak authoritatively on the indications of the use of the ligature method, a few facts may nevertheless be deduced from animal experimentation and an extensive study of the published clinical cases.

The *ligature anastomosis* is the quickest to make and the slowest to functionate. Hence, we should never resort to this method when an immediate effect is required. *Its field of usefulness is unquestionably in the various lateral intestinal anastomoses. Here the ligature method may become the method of choice.* Its adoption may be of service in the following conditions: Strangulated hernia, artificial anus, inoperable obstructive tumors of the intestine, as a preliminary step in the resection (Kocher) of large intestinal neoplasms.

In certain gastric conditions (incomplete pyloric stenosis, inveterate dyspepsia, ulceration) the elastic ligature may prove of service, but we should not overlook the fact that in these conditions the suture method in the hands of experienced men has proved eminently safe and satisfactory.

In incomplete malignant pyloric stenosis, the elastic method may prove useful at an early stage, but in late cases feeding cannot be retarded, and acute dilatation may prove dangerous. Not the least of the objections to the ligature method are the tendency to do a palliative operation rather than a radical or curative one and the frequent abuse of an apparently simple operative method.

The perusal of the published reports of the elastic ligature demonstrates the absurd use made of the method, especially in this country, for complete pyloric obstruction of benign or malignant origin. It were indeed truly difficult to preconize

* Our elastic ligature operations in man comprise three posterior gastro-enterostomies and four lateral intestinal anastomoses, all very successful.

a more perfect mode of fasting in a condition of advanced starvation.

In complete pyloric stenosis, whether of bengin or malignant origin, the ligature method is to be severely condemned.* All dogs and cats subjected to a ligature gastro-enterostomy and occlusion or exclusion of the pylorus, died of convulsive autointoxication. Chas. Mayo and Maury report similar experimental findings.

While anastomosis by the ligature method belongs logically to the class of operations in two stages, all of which have for obvious reasons been gradually abandoned, notwithstanding their apparent advantages, sufficient evidence, both experimental and clinical, has been adduced to render unquestionable the superiority of the elastic ligature in various lateral intestinal anastomoses.

On the other hand, the ever-increasing *furor operandi* and particularly the surgeon's surreptitious invasion of the medical man's domain—gastric ptosis and atonic dilatation—call for simple and truly safe surgical measures. The elastic ligature apparently fulfils both of these conditions, but prolonged clinical experience alone can determine its practical value, its indications, its limitations; and, while its simplicity of technique may render it popular with surgeons unduly fearful of peritoneal contamination and unskilled in the use of the needle, experienced men cannot, barring rare circumstances, be expected to give preference to "devices that work while the surgeons are asleep."

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* In the skillful hands of Ochsner the elastic ligature gave five deaths in a series of 28 patients with malignant obstruction of the pylorus.

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